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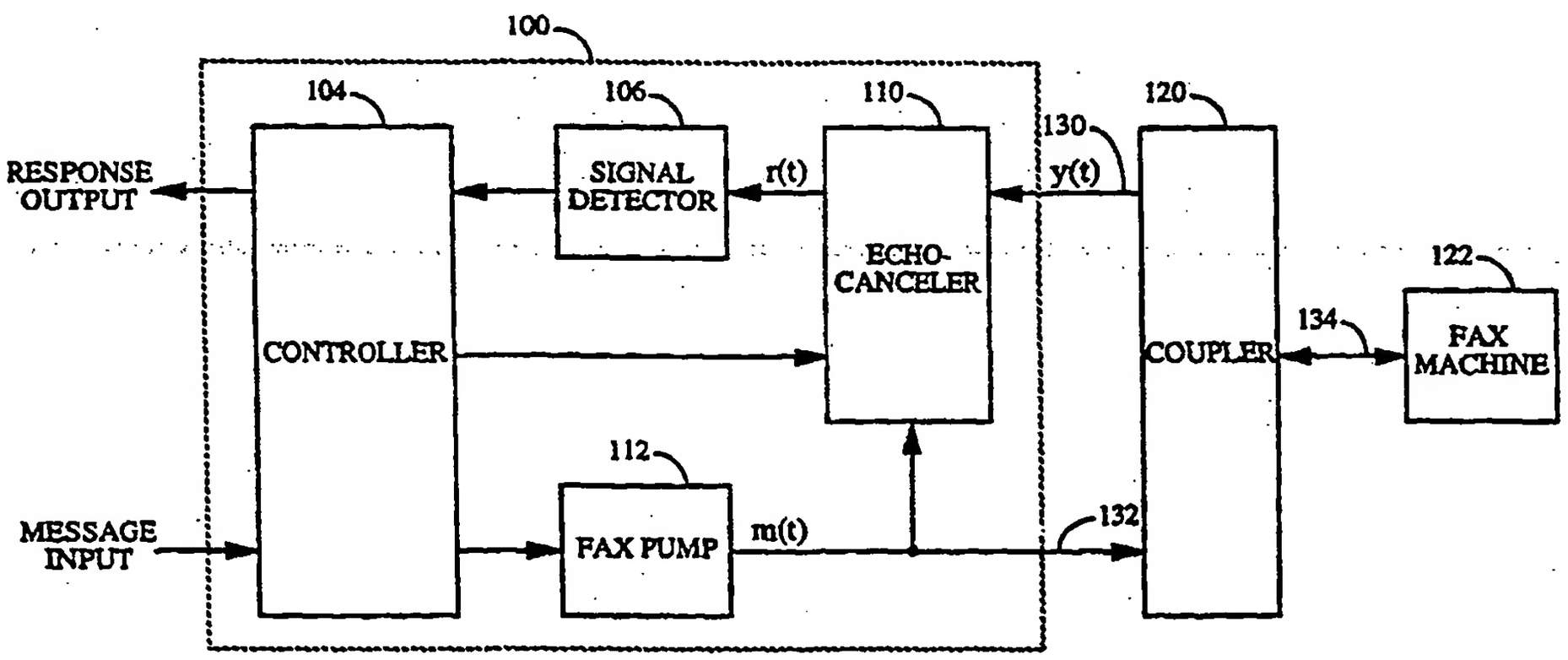

(57) Abstract

In a half–duplex communication system in which additional delays in the communication channel (18, 20) may cause a message collision between a message and a response, a collision detector (40a, 40b) is utilized to prevent and detect message collisions. The collision detector determines (204) if a response may be transmitted from the communication device while it is receiving the current message. If no response is expected, the collision detector is placed (214) into a train mode. If a response is possible, the collision detector is placed (206) into the monitor mode. In the monitor mode, the collision detector monitors the communication channel and determines (210) if a message collision has occurred during transmission of the message. A detection of a message collision causes retransmission of the message or possibly a new message at a later time after it has been determined (202) that the communication channel is clear.

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A METHOD OF AND APPARATUS FOR DETECTING AND PREVENTING MESSAGE COLLISIONS IN A COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to data transmission. More particularly, the present invention relates to novel and improved methods for preventing and detecting message collisions in a half-duplex communication system.

II. Description of the Related Art

In a half-duplex communication system, multiple communicating devices are connected to a single communication channel. One such system is a fax communication system in which two fax machines send messages across a telephone line. Half-duplex devices such as fax machines are capable of only transmitting or receiving messages at any particular instant. These devices cannot transmit and receive data simultaneously. If two devices transmit signals toward each other simultaneously and neither device is listening, the devices will not receive the other's message. This event is known as a message collision.

Most half-duplex communication systems are designed to minimize message collisions to improve the quality of the communications. These systems employ a variety of schemes to avoid message collisions. Some of these schemes require a certain quality in the communication channel. As the communication channel deteriorates, there may be an increased likelihood of message collisions. Other schemes use special timing and synchronization to avoid message collisions. For these schemes, increased delays in the communication channel may cause the system to fail.

A fax communication system is an example of a half-duplex communication system which relies on the timing and synchronization between the two communicating fax machines to avoid message collisions. The fax machines communicate with each other through a standard public switched telephone network (PSTN) channel which has known channel quality and delay characteristics. When a non-standard PSTN channel, such as a digital communication system or a satellite link, is inserted between the

two fax machines the increased transmission delays can cause the fax interactions to fail because of message collisions.

A digital communication system or satellite link is incorporated with the half-duplex communication system to extend the range of coverage, allow mobility in the communicating devices, and increase interconnectivity between different communicating devices. An exemplary digital communication system which can be used in conjunction with a fax communication system is a wireless code division multiple access (CDMA) system operating in the cellular or personal communication system (PCS) band or a GLOBALSTAR satellite communication system. These digital communication systems have inherent processing delays resulting from the large amount of digital signal processing and from transmission delays. These digital communication systems also employ central base stations to combine or multiplex signals from many communicating devices into a common transmission signal. The resultant overall delay can be both intolerably long and unpredictable.

Throughout this specification, a syntax structure is maintained to clarify the discussion of the invention. In describing communications between two devices, the term 'message' is used to denote a communication from a source device to a destination device. This 'message' may or may not be retransmitted by the source device. The term 'response' is used to denote a communication from the destination device to the source device as the result of the earlier transmitted 'message'.

In a half-duplex communication system which utilizes a timing and synchronization scheme to avoid message collision, a source device desiring to communicate with a destination device on the same channel initiates the communication by sending out a message and waiting for a response from the destination device. After a predetermined length of time passes, if no response is received, the source device retransmits the message. This process is repeated for a specified number of times or until a response is received.

For a standard Group 3 fax communication system, the timing and synchronization between fax machines conform to behavior as specified in "ITU-T Recommendation T.30 : Procedures for Document Facsimile Transmission in the General Switched Telephone Network", hereinafter referred to as the T.30 fax protocol. The T.30 fax protocol uses a number of modulation techniques for transmission of forward message data. In particular, parameter negotiation and handshaking between fax machines is

accomplished using the modulation technique specified in "CCITT Recommendation V.21 : 300 bps Duplex Modem Standard for use in the General Switched Telephone Network (GSTN)". The handshaking establishes the proper mode of communications between the fax machines.

For a T.30 fax system, a calling fax machine initiates a call by dialing the called fax machine and sending a calling tone (CNG). The called fax machine detects the incoming call and sends a called station identification tone (CED) back to the calling fax machine. The called fax machine then sends its digital identification signal (DIS) to the calling fax machine to inform the calling fax machine of its capabilities. Upon detection of the DIS signal, the calling fax machine sends a digital command signal (DCS) to inform the called fax machine of the capabilities the calling fax machine plans to use.

Other messages in addition to the above described initiation signals also take place between the fax machines during a call. For example, the training signals, information messages and termination messages are also part of a typical fax call.

A calling fax machine and a called fax machine send many messages between each other during a call. Messages are sent from either the calling fax machine or the called fax machine at various stages in a fax call. Since both calling and called fax machines can initiate messages, the discussion below describes the communications in terms of a source fax machine that initiates a message to a destination fax machine and a destination fax machine that reacts with a response back to the source fax machine without reference to calling or called fax machines. Some of the messages by the source fax machine must be repeated if no response is received for these messages.

The T.30 fax protocol specifies the procedure which must be followed when initiating a call between the fax machines. For example, the sequence and format of the CNG, CED, DIS, and DCS messages are specifically defined. The T.30 fax protocol also defines the messages which must be repeated if no response is received. Therefore, by monitoring the message format and having a priori knowledge of the signaling sequence, it is possible to determine which message will be repeated. A repeated message can be determined by analyzing the message and the state in a fax call in which it is received, as per the T.30 fax protocol.

To accommodate for unfavorable channel conditions, the T.30 fax protocol requires that certain unanswered messages between fax machines be repeated. If the source fax machine sends such a message to the

destination fax machine, the source fax machine expects a response from the destination fax machine within a specified period of time. If no response is received after the specified period of time, the T.30 fax protocol requires the source fax machine to retransmit the message. The retransmissions continue until a response from the destination fax machine is received or an excessive number of attempts have been made.

The DIS and certain messages between the fax machines are repeated at a specified repetition interval if no response is detected. The T.30 fax protocol defines the shortest repetition interval within which a retransmission is allowed. For example, the T.30 fax protocol specifies the repetition interval for a fax machine operating in automatic mode to be 3.0 sec ± 0.45 sec. This means that a fax machine conforming to the T.30 fax protocol should not retransmit a message within 2.55 sec of the prior message. Therefore, if such a fax machine receives a response within the shortest repetition interval of 2.55 sec, no collision will occur.

Under this T.30 fax timing scheme, long transmission delays in the communication channel can cause message collisions. In one scenario, the source fax machine transmits a message to the destination fax machine and, because of the transmission delays, the response from the destination fax machine takes more time than the repetition period to reach the source fax machine. Since the source fax machine does not receive the response in time, it retransmits the message. If the response from the destination fax machine arrives at the same time the source fax machine is retransmitting the message, a message collision results and the response will not be received by the source fax machine.

In an exemplary fax communication system which utilizes a standard PSTN communication system, the communication channel is typically an RJ-11 interface. The RJ-11 interface is known in the art and is composed of a pair of wire for carrying a differential signal. The use of a differential signal improves performance because of the superior noise immunity over a single-ended signal. The RJ-11 interface carries all communications between the fax machines on the same wire pair.

The 2-to-4 wire converter, a hybrid circuit also known in the art, is used to decouple the messages and responses on the RJ-11 interface. The 2-to-4 wire converter is composed of one differential pair of wire on the primary side and two differential pairs of wire on the secondary side. The differential pair of wire on the primary side connects to the RJ-11 interface which, in turn, connects to a destination fax machine. The two differential pairs of wire on the secondary side connect to a forward channel and a

reverse channel. The forward channel carries messages from a source device to the destination fax machine through the 2-to-4 wire converter. Likewise, the responses from the destination fax machine are coupled to the reverse channel through the 2-to-4 wire converter. Ideally, only messages should appear on the forward channel and only responses should appear on the reverse channel. Because of imperfections in the implementation of the 2-to-4 wire converter, small but distorted versions of the messages appear on the reverse channel and vice versa. A collision prevention/detection circuit must be able to operate with these known imperfections in the 2-to-4 wire converter.

The inability to account for unpredictable and long delays renders the communications between Group 3 fax machines on non-standard PSTN communication channel unreliable. A method is needed to detect message collisions regardless of the amount of channel delay and regardless of the source of the interfering signal.

SUMMARY OF THE INVENTION

It is an object of the invention to detect message collisions in a half-duplex communication system.

The invention provides an apparatus for preventing and detecting message collisions in a half-duplex communication system comprising : a controller means for sending a message to a communication device; an echo canceller means connected to said controller means and said communication device, said echo canceller means receiving said message from said controller means and a signal from said communication device and providing an error signal based on said message and said signal to said controller means; and a signal detector means for receiving said error signal from said echo canceller means and sending a status signal to said controller means, said status signal being dependent on said error signal from said echo canceller means.

The invention provides an apparatus for detecting message collision in a half-duplex communication system comprising : a controller for sending a message to a communication device; and a signal parameter estimator connected to said controller and said communication device, said signal parameter estimator receiving a signal from said communication device and providing a status signal based on said signal to said controller.

The invention provides a method for detecting message collision in a half-duplex communication system comprising : sending a message to a communication device; receiving a signal from said communication device; generating an error signal based on said message and said signal; and sending a status signal indicative of a presence or absence of a message collision based on said error signal.

The invention also provides a method for detecting message collision in a half-duplex communication system comprising: sending a message to a communication device; receiving a signal from said communication device; measuring an energy level of said signal and providing energy measurements; and sending a status signal indicative of a presence or absence of a message collision based on said energy measurements.

The invention also provides a circuit for preventing and detecting message collisions in a half-duplex communication system comprising: a controller for sending a message to a communication device; an echo canceller connected to said controller and said communication device, said echo canceller receiving said message from said controller and a signal from said communication device and providing an error signal based on said message and first signal to said controller; and a signal detector for receiving said error signal from said echo canceller and sending a status signal to said controller, said status signal being dependent on said error signal from said echo canceller.

The invention also provides a collision detector for use with a transmitting and receiving device for avoiding signal collisions, the detector being connectable between a transmitting and receiving device and a transmission channel for the transfer of signals therebetween and being arranged to determine whether or not the device may transmit an acknowledging signal during reception of a signal, to monitor the transmission channel for a collision, and to cause the retransmission of a signal in the event of a collision being detected.

In the practice of the invention a 2-to-4 wire converter may be interposed between the collision detector and the communication device. A message on the forward channel may be routed to the communication device through the 2-to-4 wire converter. A response from the communication device may be routed to the reverse channel through the 2-to-4 wire converter. Because of imperfections in the 2-to-4 wire converter, a portion of the message on the forward channel also appears on the reverse channel.

The detector may operate in a training period or a message transmission period. During a training period, a message is transmitted to the communication device on a forward channel. Because of imperfections in the 2-to-4 wire converter, a portion of the message appears on the reverse channel as an echo. The message is also passed through an adaptive filter to produce an estimate of the echo. During the training period, the echo canceller monitors the error signal between the echo and the estimate of the echo and adjusts the frequency response of its filter to minimize the error signal. During a message transmission period, the adaptive filter is fixed and the echo canceller measures the error signal. If a response appears on a reverse channel during transmission of the message, the collision detector declares that a message collision has occurred and outputs a status signal indicating the condition.

In an embodiment of the invention message collisions in a half-duplex communication system are detected by utilizing a signal parameter estimator. During the training period, the signal parameter estimator measures the spectral energy of the echo on the reverse channel. The signal parameter estimator then creates a set of threshold values based on the measured energy of the echo. During the message transmission period, the signal parameter estimator compares the measured spectral energy of the signal on the reverse channel and compares the measured values to the set of threshold values. If the measured values fall outside the threshold range, a message collision is declared and the signal parameter estimator outputs a status signal indicating the condition.

The foregoing, together with other objects, features and advantages of this invention, will become more apparent when referring to the following specification, claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below of an embodiment of the invention when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a block diagram of a standard half-duplex PSTN communication system in the prior art;

FIG. 2 is a block diagram of a half-duplex PSTN communication system which includes a digital communication system;

FIG. 3 is a block diagram of an echo canceller based collision prevention/detection circuit;

FIG. 4 is a block diagram of an exemplary echo canceller circuit;

FIG. 5 is a flow diagram of an echo canceller based collision detection method embodying the present invention; and

FIG. 6 is a block diagram of a parametric collision prevention/detection circuit;

FIG. 7 is a block diagram of an exemplary parametric signal detector circuit;

FIG. 8 is a flow diagram of a parametric collision detection method embodying the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An example of a known half-duplex communication system is shown in FIG. 1. One such system is a standard fax communication system. In this fax communication system, fax machine A 2 communicates with fax machine B 10 through public switched telephone network (PSTN) 6 via communication channels 4 and 8. Fax machine A 2 connects to PSTN 6 via communication channel 4. PSTN 6 connects to fax machine B 10 via communication channel 8. PSTN 6 acts as a switch to connect communication channel 4 to communication channel 8 to enable communications between the fax machines. Communication channels 4 and 8 are typically standard RJ-11 interfaces. The characteristics and delays of the RJ-11 interfaces and PSTN 6 are well defined and accounted for in the T.30 fax protocol.

A communication system which employs a wireless communication system is illustrated in FIG. 2. In this communication system, a wireless communication system is connected in series with communication channels 14 and 24 between fax machine A 12 and fax machine B 30. The digital communication system can be a terrestrial wireless CDMA system or a satellite communication system such as the GLOBALSTAR system. Fax machine A 12 communicates with single subscriber system (SSS) phone 16 through communication channel 14. In the preferred embodiment, communication channel 14 is an RJ-11 interface. SSS phone 16 demodulates and digitally processes the data and transmits the resultant output through over-the-air communication channel 18. Over-the-air communication

channel 18 can be a satellite link or a terrestrial wireless link. Base station 22 receives the over-the-air signal, processes and remodulates the signal, and sends the data to PSTN 26 through communication channel 24. Communication channel 24 is typically a standard T1/E1 line or any other similar transmission medium. PSTN 26 routes the data to FAX machine B 30 through communication channel 28.

The digital signal processing in SSS phone 16 and base station 22 delays the communications between fax machine A 12 and fax machine B 30. Signal transmissions through over-the-air communication channels 18 and 20 add to the overall delay. The total delay causes a message originating from the source fax machine to be received later by the destination fax machine. Likewise, a response from the destination fax machine arrives at the source fax machine at a later time.

In the exemplary embodiment, collision prevention/detection circuits 40a and 40b residing within the half-duplex communication system are utilized to detect message collisions between fax machine A 12 and fax machine B 30. Collision prevention/detection circuit 40a resides in SSS phone 16 and collision prevention/detection circuit 40b resides in base station 22. In the preferred embodiment, one collision prevention/detection circuit 40 is assigned to each of the two communicating fax machines.

In a call between fax machines, a fax machine behaves as a source fax machine for some messages and as a destination fax machine for other messages. In describing the present invention, it is only necessary to describe the communication between collision prevention/detection circuit 40 and a destination fax machine without regard to the source fax machine. Limiting the discussion to the collision prevention/detection circuit and the destination fax machine allows a focused discussion of the present invention without loss of scope.

I. First Embodiment

In the first embodiment, an echo canceller based collision detector is utilized to detect message collisions. An exemplary echo canceller based collision detector is shown in FIG. 3. In this embodiment, collision detector 100 connects in series with the communication channel between the fax machines. Collision detector 100 resides within SSS phone 16 and/or base station 22 (see FIG. 2) and is labeled as collision prevention/detection circuit 40 in FIG. 2. In the preferred embodiment, one collision detector 100 is assigned to each of the two communication fax machines 12 and 30. For

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clarity, the following discussion is focused on the fax communication between collision prevention/detection circuit **40a** and fax machine A **12** in FIG. 2, which are renumbered as collision detector **100** and fax machine **122** in FIG. 3. The same interaction also occurs between collision prevention/detection circuit **40b** and fax machine B **30**.

Referring to FIG. 3, echo canceller based collision detector **100** resides within SSS phone **16**. Collision detector **100** receives messages from SSS phone **16** and sends responses to SSS phone **16**. Collision detector **100** connects to coupler **120** through forward channel **132** and reverse channel **130**. Coupler **120** can be a 2-to-4 wire converter or any other hybrid coupler capable of performing the function herein described and is typically an adapter connected to the interface of SSS phone **16**. Fax machine **122** connects to coupler **120** through communication channel **134** such as an RJ-11 interface. Coupler **120** couples the messages on forward channel **132** to fax machine **122** and the responses from fax machine **122** to reverse channel **130**.

Within collision detector **100**, controller **104** connects to fax pump **112**. Controller **104** may be implemented in a microprocessor, a microcontroller, a digital signal processor (DSP) chip, or an ASIC programmed to perform the function as described. Fax pump **112** modulates the digital data from controller **104** and transmits the modulated signal as messages on forward channel **132**. Echo canceller **110** connects to controller **104**, reverse channel **130**, and forward channel **132**. Echo canceller **110** receives a control signal from controller **104** commanding echo canceller **110** into a train mode or a monitor mode. Signal detector **106** is interposed between echo canceller **110** and controller **104**. Signal detector **106** monitors the error signal from echo canceller **110** and outputs a status signal indicating the presence or absence of a message collision, based on the error signal from echo canceller **110**, to controller **104**.

If controller **104** needs to transmit a message to fax machine **122**, controller **104** first determines if communication channel **134** connected to fax machine **122** is clear. This determination is based on the status signal from signal detector **106**. If communication channel **134** is not clear, controller **104** waits for the channel to clear before proceeding.

Based on the type of the message to be sent to fax machine **122** and its *a priori* knowledge of the T.30 fax protocol, controller **104** knows whether a response will be forthcoming from fax machine **122** as the result of receiving the message. If no response is expected from fax machine **122**, a message collision is highly unlikely and controller **104** sends a control signal to echo canceller **110** to command echo canceller **110** into the train mode. Controller

104 then sends the message data to fax pump **112**. Fax pump **112** receives the message data from controller **104**, modulates the data, and transmits the modulated signal as a message on forward channel **132**. A predominant portion of the message is coupled to fax machine **122** through coupler **120**. Because of imperfections in the implementation of coupler **120**, an echo y(t) of the message appears on reverse channel **130**. For a linear system, the echo is a small, time delayed, and amplitude distorted version of the message. The echo appears on reverse channel **130** as the result of internal coupling within coupler **120**. Since it has been determined previously that communication channel **134** is clear before the transmission of the message, only the echo is present on reverse channel **130**.

The message m(t) is also passed through an adaptive filter which resides within echo canceller **110**. The design and implementations of echo cancellers are well known in the art. The exemplary embodiment of echo canceller **110** is described in detail in U.S. Patent No. 5,307,405, entitled "NETWORK ECHO CANCELLER" which is assigned to the assignee of the present invention and incorporated by reference herein. The adaptive filter adjusts its frequency response characteristics, e.g. its amplitude and delay response versus frequency, such that the filter output is a close estimate of the echo on reverse channel **130**. The adaptive filter minimizes the error r(t) between the echo and the estimate of the echo by adjusting the frequency response of the filter according to an adaptive procedure. The adaptive procedure can be a least-mean-square (LMS) algorithm or any other signal estimation technique suitable for the task herein disclosed. When transmission of the message is complete, controller **104** terminates the training period and the frequency response of the adaptive filter is fixed. No adjustment is made on the adaptive filter frequency response until the next training period.

During transmission of messages from controller **104** to fax machine **122**, controller **104** sends a control signal to echo canceller **110** to place echo canceller **110** into the monitor mode. In this mode, echo canceller **110** estimates the echo on reverse channel **130** by filtering the message with the adaptive filter. Since echo canceller **110** has just been trained, the estimate at adaptive filter **116** output is a close approximation of the echo on reverse channel **130**. As the result, the error signal r(t) between the echo estimate and the echo will be a small signal. Signal detector **106** compares the error signal to a predetermined threshold and outputs a status signal to controller **104** indicating that the error signal is below the predetermined threshold and that no message collision has occurred.

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Due to excessive transmission delays or incorrect synchronization, fax machine **122** may transmit a response during transmissions of the messages. In this instant, the signal on reverse channel **130** is composed of the echo of the message and the response from fax machine **122** which are coupled to reverse channel **130** by coupler **120**. Echo canceller **110** is only able to estimate the echo of the message. Therefore, the error signal r(t) between the echo estimate and the signal on reverse channel **130** will be composed predominately of the response from fax machine **122**. Signal detector **106** compares the error signal against the predetermined threshold. If the error signal exceeds the predetermined threshold because of the presence of the response from fax machine **122**, signal detector **106** outputs a status signal to controller **104** indicating that a large signal is present on communication channel **134** and that there is a high likelihood of a message collision. Controller **104**, upon receipt of the status signal indicating a high likelihood of a message collision, terminates transmission of the message, continuously monitors the status signal, and retransmits the message at a later time after it has been determined that communication channel **134** is clear.

By utilizing an echo canceller based collision detector to detect message collisions, communications between fax machines in the presence of long channel delays and/or deteriorating channel conditions is greatly improved.

A simplified version of the exemplary echo canceller is shown in FIG. 4. As shown in the figure, a message m(t) is transmitted by fax pump **112** to fax machine **122** on forward channel **132** through coupler **120**. Coupler **120** directs a predominant portion of the message from forward channel **132** to communication channel **134**. The message is also coupled to reverse channel **130** due to internal coupling within coupler **120**. As a result, an echo is introduced on reverse channel **130**.

Echo canceller **110** estimates the echo on reverse channel **130** based on the message. Filter **116** is applied to the message to produce an estimate of the echo. Different filter implementations such as analog filters, non-linear filters, or digital filters such as a finite impulse response (FIR) or an infinite impulse response (IIR) filter synthesized in hardware or software can also perform the filtering function and are within the scope of the present invention. In the exemplary embodiment, filter **116** is an FIR filter. Summer **108** is a difference amplifier with inputs connected to reverse channel **130** and FIR filter **116**. Summer **108** can be implemented with a differential amplifier or other signal combining circuits. Summer **108**

outputs an error signal that is the difference between the signal y(t) on reverse channel **130** and the estimate y'(t) of the echo from FIR filter **116**.

The coefficients of FIR filter **116** are provided by coefficient update circuit **114**. Coefficient update circuit **114** receives the error signal r(t) from summer **108** and calculates a set of filter coefficients for FIR filter **116** which minimize the error signal r(t). The coefficient calculation can be performed by one of any number of adaptive routines. In the preferred embodiment, the coefficient calculation is performed by a least-mean-square (LMS) algorithm that is known in the art. Coefficient update circuit **114** also receives the control signal from controller **104** which commands coefficient update circuit **114** into the train mode or the monitor mode. Training is enabled only during the transmission of the message and only after controller **104** has determined that no other interfering signals, such as a response , is present on communication channel **134** (see FIG. 3). Coefficient update circuit **114** only updates the filter coefficients during the training period. During the monitor mode, coefficient update circuit **114** is disabled and the previously calculated filter coefficients are maintained by FIR filter **116**.

The accuracy of the echo estimate is dependent on the FIR filter implementation. More filter taps and greater mathematical precision in the implementation of the FIR filter allow for a more accurate estimate of the echo at the expense of greater complexity. As a minimum, the echo must be canceled sufficiently such that the resulting error signal r(t) consistently falls below the predetermined threshold.

The predetermined threshold is determined by system considerations. The threshold must be set low enough to enable detection of all responses from fax machine **122**. However, setting the threshold too low may result in erroneous indications of message collisions. In the preferred embodiment, the threshold is set at a level which, if exceeded by the response , would cause incorrect reception of the message by fax machine **122** but which does not erroneously indicate message collisions.

In the preferred embodiment, signal detector **106** uses the techniques described in U.S. Patent Application Serial No. 08,857,343, entitled "METHOD AND APPARATUS FOR DETECTING FACSIMILE TRANSMISSION", hereinafter the 08,857,343 patent application, filed May 16, 1997, assigned to the assignee of the present invention and incorporated by reference herein, to detect the presence of fax messages in the error signal r(t). V.21 messages are transmitted using binary frequency shift keying (BFSK) modulated signals where 1650Hz represents binary '1' and 1850Hz

represents binary '0'. As described in the 08,857,343 patent application, the error signal r(t) is filtered by two notch filters, one centered at 1650Hz and the second centered at 1850Hz. The outputs from the notch filters are separately squared and accumulated over a predetermined interval to obtain energy values. Signal detector **106** analyzes the present and prior energy values, e.g. comparing these energy values to a known energy signature. If the energy values conform to a predetermined criteria, e.g. as specified in the 08,857,343 patent application, a message collision is indicated on the status signal sent to controller **104**

In an alternative embodiment, signal detector **106** compares the error signal r(t) against the predetermined threshold. In this embodiment, signal detector **106** can be implemented with a comparator or other signal comparison circuits. In one embodiment, signal detector **106** compares the error signal to one predetermined threshold. If the error signal exceeds the predetermined threshold, a message collision is indicated on the status signal sent to controller **104**. In another embodiment, multiple thresholds are utilized to indicate message collisions with varying degree of certainty. An error signal exceeding each of the multitude of thresholds would be equated with a different probability of message collision. These and other variations of signal detector **106** are within the scope of the present invention.

A flow diagram describing the operation of the echo canceller based collision detector of the first embodiment is shown in FIG. 5. Initially, the collision detector has a message to send to the fax machine at state **200**. The collision detector first checks the communication channel connected to the fax machine to determine whether the channel is clear at step **202**. If the channel is not clear, the collision detector continues to monitor the channel and will proceed only after it has been determined that the channel has become clear.

At step **204**, the collision detector analyzes the message to determine whether it is possible to receive a response from fax machine **122** while fax pump **112** is transmitting the message. The collision detector is able to determine this based on its knowledge of the type of the message to be transmitted and its a priori knowledge of the T.30 fax protocol. If no response from the fax machine is expected, the potential for message collision is minimal. The echo canceller is then placed into the train mode while the message is being transmitted by the fax pump to the fax machine at step **214**.

In the train mode, the echo canceller attempts to minimize the difference between the echo on the reverse channel and an estimate of the echo. The estimate of the echo is derived by filtering the message with an adaptive filter. The echo canceller attempts to minimize the error of the estimate by adjusting the filter characteristics. The train mode continues until transmission of the message is complete. Upon completion of the transmission, the collision detector terminates the process at state **220**.

If in step **204**, the collision detector determines that it is possible to receive a response from fax machine **122** while fax pump **112** is transmitting the message to it, the echo canceller is commanded into the monitor mode at step **206**. The collision detector then directs the fax pump to transmit the message to the fax machine at step **208**. While transmission continues, the collision detector enters into a loop to continually check for message collision during the transmission of the message. The first step in the loop involves monitoring the signal on the reverse channel at step **210** for an interfering signal from the communication channel. The interfering signal can be a response from the fax machine . If no interfering signal is detected, the collision detector then determines if the transmission of the message has been completed at step **218**. If transmission is not complete, collision detector continues to transmit the message at step **216** and returns to step **210**. Upon determination that the complete message has been transmitted, the process terminates at state **220**.

If the collision detector detects the presence of an interfering signal on the communication channel during transmission of the message at step **210**, the collision detector commands the fax pump to terminate the transmission at step **212**. The collision detector then continues to monitor the communication channel until it has been determined that the interfering signal has disappeared at step **202**. Once the channel is clear, the collision detector retransmits the message starting at step **204**.

In another embodiment, signal detector **106** in FIG. 3 also includes a signal demodulator. When a signal is detected in the error signal r(t), the demodulator decodes the signal and determines the content of the response from fax machine **122**. This response is passed to controller **104**. Then, based on this response and the current state in the T.30 fax protocol, controller **104** decides whether to retransmit the last message, wait, or send a new message to fax machine **122**.

II. Second Embodiment

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In the second embodiment, a parametric collision detector is utilized to detect message collisions. An exemplary parametric collision detector is shown in FIG. 6. In this embodiment, parametric collision detector **102** connects in series with the communication channel between the fax machines. Collision detector **102** resides within SSS phone **16** and/or base station **22** (see FIG. 2) and is labeled as collision prevention/detection circuit **40** in FIG. 2. In the preferred embodiment, one collision detector **102** is assigned to each of the two communication fax machines **12** and **30**. For clarity, the following discussion is limited to the communication between collision prevention/detection circuit **40a** and fax machine A **12** in FIG. 2 which are renumbered as collision detector **102** and fax machine **122** in FIG. 6. The same interaction also occurs between collision prevention/detection circuit **40b** and fax machine B **30**.

Referring to FIG. 6, parametric collision detector **102** resides within SSS phone **16**. Collision detector **102** receives messages from SSS phone **16** and sends responses to SSS phone **16**. Collision detector **102** connects to coupler **120** through forward channel **132** and reverse channel **130**. Coupler **120** can be a 2-to-4 wire converter or any other hybrid coupler capable of performing the function herein described and is typically an adapter connected to the interface of SSS phone **16**. Fax machine **122** connects to coupler **120** through communication channel **134** such as an RJ-11 interface. Coupler **120** couples the messages on forward channel **132** to fax machine **122** and the responses from fax machine **122** to reverse channel **130**.

Within collision detector **102**, controller **144** connects to fax pump **146**. Controller **144** may be implemented in one of many manners described previously in the first embodiment. Fax pump **146** modulates the digital data from controller **144** and transmits the modulated signal as messages on forward channel **132**. Signal parameter estimator **148** connects to controller **144**, fax pump **146**, and reverse channel **130**. Signal parameter estimator **148** receives the digital data from fax pump **146** and the signal on reverse channel **130** and determines whether a message collision has occurred based on these two inputs. Signal parameter estimator **148** also receives a control signal from controller **144** which commands signal parameter estimator **148** into a train mode or a monitor mode. Finally, signal parameter estimator **148** provides a status signal to controller **144** to indicate the presence or absence of a message collision.

Sending a message from controller **144** to fax machine **122** occurs in the same manner in the second embodiment as in the first embodiment. If controller **144** needs to transmit a message to fax machine **122**, controller **144**

first determines if communication channel **134** connected to fax machine **122** is clear. To determine this, controller **144** uses the status signal from signal parameter estimator **148**. Controller **144** proceeds only after it has been determined that the communication channel is clear and that there is no potential for message collisions.

Based on the type of the message to be sent to fax machine **122** and its a priori knowledge of the T.30 fax protocol, controller **144** knows whether it is possible to receive a response from fax machine **122** while fax pump **146** is transmitting the message. If no response is anticipated from fax machine **122**, a message collision is highly unlikely and controller **144** sends a control signal to signal parameter estimator **148** to command signal parameter estimator **148** into the train mode. Controller **144** then sends the digital data to fax pump **146**. Fax pump **146** receives the digital data, modulates the data, and transmits the modulated signal as a message on forward channel **132**. Coupler **120** couples a predominant portion of the message from forward channel **132** to communication channel **134** connected to fax machine **122**. Again, due to imperfections in the implementation of coupler **120**, a small and distorted version of the message appears on reverse channel **130**. This echo from the message is the only signal present on reverse channel **130** since it has just been determined, before the transmission of the message, that the communication channel is clear.

In the train mode, signal parameter estimator **148** monitors the echo on reverse channel **130** as fax pump **146** transmits the message. The digital data comprising the message is also sent by fax pump **146** to signal parameter estimator **148**. Thus, during the training period, signal parameter estimator **148** has the digital data and the echo corresponding to the digital data. Signal parameter estimator **148** computes the values for various predetermined parameters of the echo. As an example, signal parameter estimator **148** can compute the energy of the echo within different frequency bands. The energy measurement at each frequency band would then be mapped to a distinct parameter of the echo. The computed values, e.g. the energy measurements at different frequency bands, are then equated to the digital bits that produced in those computed values. Thus, after signal parameter estimator **148** has been trained, signal parameter estimator **148** is able to predict what the computed values for the parameters should be, based solely on the digital data from fax pump **146**. Signal parameter estimator **148** uses the predicted values to create sets of threshold values for these parameters, one set of threshold values for each parameter, and each set of threshold values forming a threshold range.

If controller **144** expects a possible response from fax machine **144** while fax pump **146** is transmitting a message, controller **144** sends a control signal to signal parameter estimator **148** to command signal parameter estimator **148** into the monitor mode. By monitoring reverse channel **130**, signal parameter estimator **148** is able to detect the presence of interfering signals, such as a response from fax machine **122**. In the monitor mode, signal parameter estimator **148** receives the signal y(t) on reverse channel **130**, computes the various parameters for the signal y(t), and compares the computed values to the threshold values. If the communication channel is clear of interfering signals, the signal y(t) on reverse channel **130** will only contain the echo of the message. The computed values for the various parameters for the echo will fall within the threshold range and signal parameter estimator **148** will output a status signal to controller **144** indicating no message collision.

If fax machine **122** transmits a response to controller **144** during transmission of the message, the signal y(t) on reverse channel **130** would contain the echo plus the interfering signals. The computed values for the total signal will be different than that of the echo alone. If the computed values falls outside the threshold range, signal parameter estimator **148** outputs a status signal to controller **144** indicating the high likelihood of a message collision. Controller **144**, upon receipt of the status signal indicating the high likelihood of a message collision, terminates transmission of the message, continuously monitors the status signal, and retransmits the messages at a later time after it has been determined that the communication channel is clear. Thus, signal parameter estimator **148** is able to detect message collisions on the communication channel regardless of the source of the message collision.

By utilizing a parametric collision detector to detect collisions in the messages being transmitted to fax machine **122** and retransmitting the messages at a later time when the channel is clear, a reliable communication between controller **144** and fax machine **122** is possible.

An exemplary signal parameter estimator based on the energies at two frequency bands is shown in FIG. 7. For V.21 messages and responses, binary frequency shift keying (BFSK) is used to modulate the data bits corresponding to the messages. The modulation function is performed by fax pump **146**. A digital zero is represented by a 3.3 msec burst of 1850Hz tone and a digital one is represented by a 3.3 msec burst of 1650Hz tone. By measuring the energy of the modulated signal at these two frequencies, a

prediction can be made as to what data bits are transmitted on the communication channel.

The energy measurements at two frequency bands can also be used to determine the presence of message collisions on a communication channel due to the fact that the energy signature of an echo is different from the energy signature of an echo plus a response. For example, if communication channel **134** is clear, the signal on reverse channel **130** is composed predominately of the echo of the message on forward channel **132**. Signal parameter estimator **148** measures the energy at the two frequency bands (f_0=1850Hz and f_1=1650Hz) for each transmitted data bit. The two energy measurements for each data bit form an energy signature for that bit. The energy measurements of the echo which result from the transmission of a digital zero on forward channel **132** contain a high energy measurement at f_0=1850Hz and a low energy measurement at f_1=1650Hz. Alternately, the energy measurements of the echo which result from the transmission of a digital one contain a high energy measurement at f_1=1650Hz and a low energy measurement at f_0=1850Hz. Thus, the energy signature of the echo resulting from a digital zero transmission is different than the energy signature of a digital one transmission. The energy signatures measured during the training period are used to generate two sets of threshold values, one set for a digital zero transmission and another set for a digital one transmission. For example, the energy signature of the echo resulting from a digital zero transmission results in an upper and a lower threshold value for f_0=1850Hz and an upper and a lower threshold value for f_1=1650Hz. The energy signature for a digital one transmission also results in a set of four threshold values. The threshold values are selected such that the energy measurements of the echo alone will fall within the upper and lower thresholds. The four threshold values for each data bit form a threshold range for that bit. The energy signatures of the signal on the communication channel during subsequent message transmissions are compared against the two threshold ranges.

If the signal on reverse channel **130** contains the echo and a response from fax machine **122**, the energy signature of the echo plus the response will be different than the energy signature of the echo alone. Assuming that the response is also a V.21 message, which is true in most situation of interest, the echo and the response may add constructively or destructively. Therefore, the energy measurements at f_0=1850Hz and f_1=1650Hz of the echo plus the response will deviate from the expected energy signature of the echo alone. By comparing the energy signature of the echo plus the

response to the threshold range for the data bit being transmitted, a message collision can be determined if the measured energy signature falls outside the threshold range.

Multiple threshold ranges comprised of additional upper and lower threshold values can also be used to allow detection of message collisions with varying degree of confidence. Also, energy measurements at more than two frequency bands can also be use to allow a more accurate detection of the echo and the response. More frequency bands create a more complex energy signature and enable the resolution of other spectral components. The use of multiple ranges and multiple frequency bands, and other similar variations, are within the scope of the present invention.

In the preferred embodiment, the energy measurements at the two frequency bands are differentially combined into one combined energy value. This implementation has the advantage of simplicity but results in some loss in accuracy. The energy measurement from f_1=1650Hz is subtracted from the energy measurement at f_0=1850Hz. Thus, during the training period in which only the echo of the message is being measured, the energy measurement of the echo resulting from the transmission of a digital zero results in a high energy measurement (E_{fo}) at f_0=1850Hz and a low energy measurement (E_{f1}) at f_1=1650Hz. Differentially combining the energy measurements (E_{fo} - E_{f1}) yields a positive combined energy value for a digital zero. Alternately, the energy measurement of the echo resulting from the transmission of a digital one results in a high energy measurement at f_1=1650Hz and a low energy measurement at f_0=1850Hz. Differentially combining the energy measurements (E_{fo} - E_{f1}) yields a negative combined energy value for a digital one.

The combined energy values measured during the training period are used to generate two sets of threshold values. For example, the combined energy value of the echo resulting from a digital zero transmission results in an upper and lower threshold value centered about a positive value. The combined energy value for a digital one transmission also results in a set of two threshold values centered about a negative value. The threshold values are selected such that the combined energy value of the echo alone falls within the upper and lower thresholds. The two threshold values for a digital zero transmission form one threshold range and the two threshold values for a digital one transmission form another threshold range. The combined energy values of the signal on the communication channel during subsequent message transmissions are compared against the two threshold ranges.

If the signal on reverse channel **130** contains the echo plus a response from fax machine **122**, the combined energy value for the echo and the response will be different than the combined energy value of the echo alone. By comparing the combined energy value of the echo plus the response to the threshold range for the data bit being transmitted, a message collision is indicated if the combined energy value falls outside the threshold range. Thus, with *a priori* knowledge that the message and the response transmissions on the same frequency is highly unlikely, a signal parameter estimator which measures the energy at two subcarrier frequencies can be used to detect message collisions.

The parametric collision detector of the preferred embodiment which is based on the difference in energies at two frequency bands is shown in FIG. 7. Referring to FIG. 7, bandpass filters **158** and **160** are connected to reverse channel **130** to enable collision detector **148** to monitor communication channel **134** (not shown in FIG. 7). Bandpass filters of various types (e.g. Butterworth, Gaussian, or Chebychev), order, implementations (e.g. analog or digital filters), and bandwidths are all within the scope of the present invention. Bandpass filters **158** and **160** filter the signal on reverse channel **130** at two different frequencies, f_0 and f_1, respectively, and output the filtered signals to energy estimators **154** and **156**. In the preferred embodiment, f_0 and f_1 correspond to the two subcarrier frequencies used to frequency shift keying (FSK) modulate a digital zero (f_0=1850Hz) and a digital one (f_1=1650Hz), respectively.

Energy estimators **154** and **156** compute the energy of the filtered signals from bandpass filters **158** and **160**, respectively. The energy calculation can be performed with analog circuits or computed digitally. The outputs from energy estimators **154** and **156** are then routed to summer **152** which differentially combines the signals. Summer **152** can be implemented with a differential amplifier, an arithmetic logic unit, or other signal combining means. The combined energy value from summer **152** is routed to decision circuit **150**. Decision circuit **150** also receives the data bits corresponding to the transmitted message from fax pump **146** and a control signal from controller **144**. Decision circuit **150** outputs a status signal to controller **144** indicating the presence or absence of a message collision.

Decision circuit **150** is commanded into a train mode or a monitor mode by controller **144** through the control signal. When controller **144** determines that a message collision is unlikely based on the type of the message to be transmitted and its a priori knowledge of the T.30 fax protocol, controller **144** commands signal parameter estimator **148** into the train

mode. In the train mode, decision circuit **150** monitors the combined energy values from summer **152** and equates the combined energy values to the data bits which resulted in the echo. Since it has been determined that the communication channel is clear before placing decision circuit **150** into the train mode, the combined energy values from summer **152** will be composed predominately of the echo only. Thus, after having been trained, decision circuit **150** is able to predict what the combined energy value for the echo should be for a digital zero or a digital one transmission. Decision circuit **150** then creates two sets of threshold values, one set of threshold values for a digital zero transmission and another set of threshold values for a digital one transmission. Each set of threshold values contains an upper and a lower threshold value. The threshold values are a function of the predicted combined energy value for each bit being transmitted. The threshold values are then used later to determine the presence or absence of message collisions. The combined energy values from summer **152** can take on positive and negative values.

During transmission of the message when a message collision is possible, controller **144** commands signal parameter estimator **148** into the monitor mode. In this mode, signal parameter estimator **148** measures the energy of the signal on reverse channel **130**. The signal on reverse channel **130** is composed of the echo of the message being transmitted and interfering signals on communication channel **134**. The interfering signal can be a response from fax machine **122**. Decision circuit **150** receives the data bits from fax pump **146**, recalls the threshold values corresponding to each data bit being transmitted, and compares the combined energy value from summer **152** to the threshold values. If the combined energy value falls within the threshold range, decision circuit **150** declares no message collision has occurred. If the combined energy value falls outside the threshold range, decision circuit **150** declares that there is a high likelihood of a message collision. As discussed previously, multiple sets of threshold values can be used to allow indication of a message collision with varying degree of confidence. Decision circuit **150** sends the appropriate status signal to controller **144** indicating the condition. Upon receipt of the status signal from decision circuit **150** indicating a high likelihood of a message collision, controller **144** commands fax pump **146** to terminate transmission of the message and retransmits the message at a later time after it has been determined that the communication channel is clear.

A flow diagram detailing the operation of the parameter collision detector of the second embodiment is shown in FIG. 8. Initially, the

collision detector has a message to send to the fax machine at state 228. The collision detector first checks the communication channel connected to the fax machine to determine whether the channel is clear at step 230. If the channel is not clear, the collision detector continues to monitor the channel and will proceed only after it has been determined that the channel has become clear.

The collision detector then begins transmitting the message to the fax machine at step 232. At step 234, upon transmission of the message, the collision detector analyzes the message to determine whether it is possible to receive a response from the fax machine while fax pump 146 is transmitting the message. The collision detector is able to determine this based on its knowledge of the type of the message and its a priori knowledge of the T.30 fax protocol. If no response from the fax machine is expected, the potential for collision is minimal. The signal parameter estimator is then placed into the train mode while the message is transmitted to the fax machine at step 242.

In the train mode, the signal parameter estimator monitors the echo on the reverse channel and computes the values for various parameters of the echo. The signal parameter estimator then equates the computed values to the data bits corresponding to the echo and creates sets of threshold values for these parameters. The new threshold values update the previous threshold values within the signal parameter estimator. The train mode continues until transmission of the message is complete. The process terminates upon completion of the transmission of the message at state 250.

If the collision detector determines that it is possible to receive a response from the fax machine, the signal parameter estimator is commanded into the monitor mode. The collision detector then enters into a loop to continually check for message collision during the transmission of the message. In the first step of the loop, the signal parameter estimator computes the values for various parameters of the signal on the reverse channel to determine the presence of an interfering signal on the communication channel at step 236. The interfering signal can be a response from the fax machine. If the computed values are within the threshold values for these parameters, no message collision has occurred. The collision detector then determines whether transmission of the message has been completed at step 246. If the transmission is not complete, the collision detector continues to transmit the message at step 244 and returns to step 236. The process terminates upon determination that the complete message has been transmitted at state 250.

If the collision detector detects the presence of an interfering signal on the communication channel during transmission of the message at step 238, the collision detector commands the fax pump to terminate the transmission at step 240. The collision detector then continues to monitor the communication channel until it has been determined that the communication channel is clear. When the channel is clear, the collision detector retransmits the message starting at step 230.

The collision prevention/detection circuits in FIGS. 3 and 6 and the flow diagrams in FIGS. 5 and 8 can be implemented in a variety of methods. The inventive concept can be implemented in hardware using a state machine, some memory, and a clock. The invention can also be implemented in firmware by microcode running on a microcomputer or a digital signal processor. Other implementations or a hybrid combination of implementations are within the scope of the present invention.

Although the exemplary embodiment is directed toward a fax communication system operating in a half-duplex manner over the PSTN, the inventive concept is applicable toward any communications between multiple devices using a half-duplex communication system. For example, the present invention can be directed toward communications between computers, fax machines, scanners, plotters, and printers, copiers, test equipment, and diagnostic equipment.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WHAT I CLAIM IS:

CLAIMS

1. An apparatus for preventing and detecting message collisions in a half-duplex communication system comprising :

a controller means for sending a message to a communication device;

an echo canceller means connected to said controller means and said communication device, said echo canceller means receiving said message from said controller means and a signal from said communication device and providing an error signal based on said message and said signal to said controller means; and

a signal detector means for receiving said error signal from said echo canceller means and sending a status signal to said controller means, said status signal being dependent on said error signal from said echo canceller means.

2. The apparatus of claim 1 wherein said echo canceller means further receives a control signal from said controller means commanding said echo canceller means into a train mode or a monitor mode.

3. The apparatus of claim 2 wherein said signal detector means comprises at least one threshold level to which said error signal is compared against and wherein said status signal indicates which one of said at least one threshold level is exceeded by said error signal.

4. The apparatus of claim 2 wherein said signal detector means comprises energy calculator means to calculate energy values of said error signal, wherein said status signal is dependent on said energy values.

5. The apparatus of claim 2 wherein said echo canceller means comprises a signal estimator means.

6. The apparatus of claim 5 wherein said signal estimator means comprises an adaptive filter means.

7. The apparatus of claim 6 wherein said adaptive filter means comprises a FIR filter means and an coefficient update circuit means.

8. The apparatus of claim 7 wherein said coefficient update circuit means is a least-mean-square algorithm and wherein said coefficient update

circuit means is enabled during the train mode and disabled during the monitor mode.

9. An apparatus for detecting message collision in a half-duplex communication system comprising :

a controller for sending a message to a communication device; and

a signal parameter estimator connected to said controller and said communication device, said signal parameter estimator receiving a signal from said communication device and providing a status signal based on said signal to said controller.

10. The apparatus of claim 9 wherein said signal parameter estimator further receives a control signal from said controller commanding said signal parameter estimator into a train mode or a monitor mode.

11. The apparatus of claim 10 wherein said signal parameter estimator comprises :

at least one energy estimator for receiving said signal from said communication device, each one of said energy estimator measuring an energy level of said signal and providing an energy measurement,

a decision circuit means connected to each one of said energy estimator for receiving said energy measurements from each one of said energy estimator, said decision circuit providing said status signal based on said energy measurements to said controller.

12. The apparatus of claim 11 wherein said signal parameter estimator further comprises :

at least one bandpass filter, one bandpass filter for each energy estimator, each bandpass filter connected in series to one of said energy estimator, each bandpass filter receiving said signal from said communication device and filtering said signal at a distinct frequency to obtain a filtered signal, said filtered signal being provided to one of said energy estimator.

13. The apparatus of claim 12 wherein said signal parameter estimator comprises a first bandpass filter and a second bandpass filter and a first energy estimator and a second energy estimator.

14. The apparatus of claim 13 wherein said first bandpass filter is centered around 1850Hz and said second bandpass filter is centered around 1650Hz.

15. The apparatus of claim 14 wherein said signal parameter estimator further comprises :

a summer connected to said first energy estimator and said second energy estimator, said summer differentially combining said energy measurements from said first energy estimator and said second energy estimator, said summer also connected to said decision circuit and providing a combined energy value to said decision circuit.

16. The apparatus of claim 15 wherein said decision circuit comprises at least one set of threshold values to which said combined energy value is compared against and wherein said status signal indicates which one of said set of threshold values is exceeded by said combined energy value.

17. A method for detecting message collision in a half-duplex communication system comprising :

sending a message to a communication device;

receiving a signal from said communication device;

generating an error signal based on said message and said signal; and

sending a status signal indicative of a presence or absence of a message collision based on said error signal.

18. The method of claim 17 further comprising :

receiving a control signal commanding a train mode or a monitor mode.

19. The method of claim 18 further comprising :

comparing said error signal to at least one threshold level; and

wherein said status signal is indicative of which one of said threshold level is exceeded by said error signal.

20. The method of claim 18 further comprising :

calculating energy values of said error signal, wherein said status signal is dependent on said energy values.

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21. The method of claim 18 further comprising :

filtering said message with an adaptive filter to generate an estimated signal; and

wherein said error signal is based on said estimated signal and said signal from said communication device.

22. The method of claim 21 further comprising :

adjusting a frequency response of said adaptive filter during said training mode and maintain said frequency response during said monitor mode.

23. A method for detecting message collision in a half-duplex communication system comprising :

sending a message to a communication device;

receiving a signal from said communication device;

measuring an energy level of said signal and providing energy measurements; and

sending a status signal indicative of a presence or absence of a message collision based on said energy measurements.

24. The method of claim 23 further comprising :

filtering said signal from said communication device with at least one bandpass filter to provide filtered signals, each bandpass filter having a distinct center frequency; and

wherein said measuring step measures said energy level of said filter signal from each bandpass filter to provide said energy measurements.

25. The method of claim 24 wherein said filtering step filters said signal with two bandpass filters centered at 1850Hz and 1650Hz to provide two filtered signals and wherein said measuring step measures said energy levels of said filter signals from said bandpass filters to provide said energy measurements.

26. The method of claim 25 further comprising :

differentially combining said energy measurements from said bandpass filters to provide a combined energy value; and wherein said status signal is based on said combined energy value.

27. The method of claim 26 further comprising :

comparing said combined energy value to at least one threshold level; and

wherein said status signal indicates which one of said threshold level is exceeded by said combined energy value.

28. A circuit for preventing and detecting message collisions in a half-duplex communication system comprising :

a controller for sending a message to a communication device;

an echo canceller connected to said controller and said communication device, said echo canceller receiving said message from said controller and a signal from said communication device and providing an error signal based on said message and first signal to said controller; and

a signal detector for receiving said error signal from said echo canceller and sending a status signal to said controller, said status signal being dependent on said error signal from said echo canceller.

29. The circuit of claim 28 wherein said echo canceller further receives a control signal from said controller commanding said echo canceller into a train mode or a monitor mode.

30. The circuit of claim 29 wherein said signal detector comprises at least one threshold level to which said error signal is compared against and wherein said status signal indicates which one of said threshold level is exceeded by said error signal.

31. The circuit of claim 29 wherein said signal detector comprises energy calculators to calculate energy values of said error signal, wherein said status signal is dependent on said energy values.

32. The circuit of claim 29 wherein said echo canceller comprises a signal estimator.

33. The circuit of claim 32 wherein said signal estimator is an adaptive filter.

34. The circuit of claim 33 wherein said adaptive filter comprises a FIR filter and an coefficient update circuit.

35. The circuit of claim 34 wherein said coefficient update circuit is a least-mean-square algorithm and wherein said coefficient update circuit is enabled during the train mode and disabled during the monitor mode.

36. A collision detector for use with a transmitting and receiving device for avoiding signal collisions, the detector being connectable between a transmitting and receiving device and a transmission channel for the transfer of signals therebetween and being arranged to determine whether or not the device may transmit an acknowledging signal during reception of a signal, to monitor the transmission channel for a collision, and to cause the retransmission of a signal in the event of a collision being detected.

FIG. 1

PRIOR ART

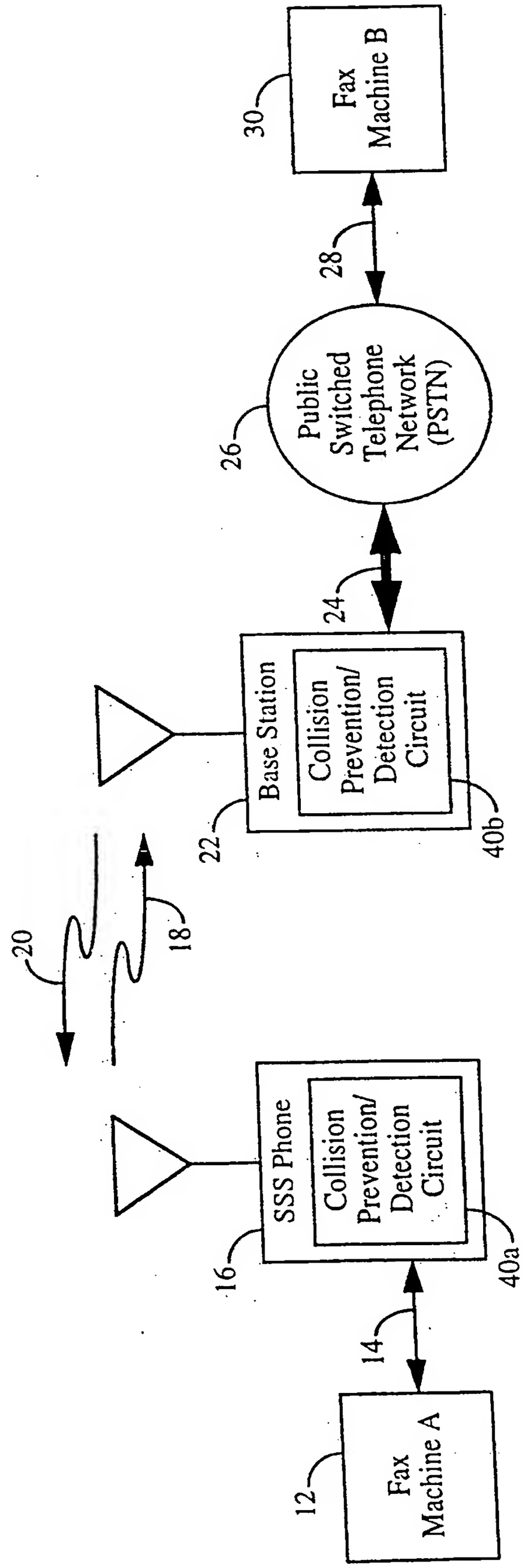


FIG. 2

BNSDOCID: <WO_____9852299A1_I_>

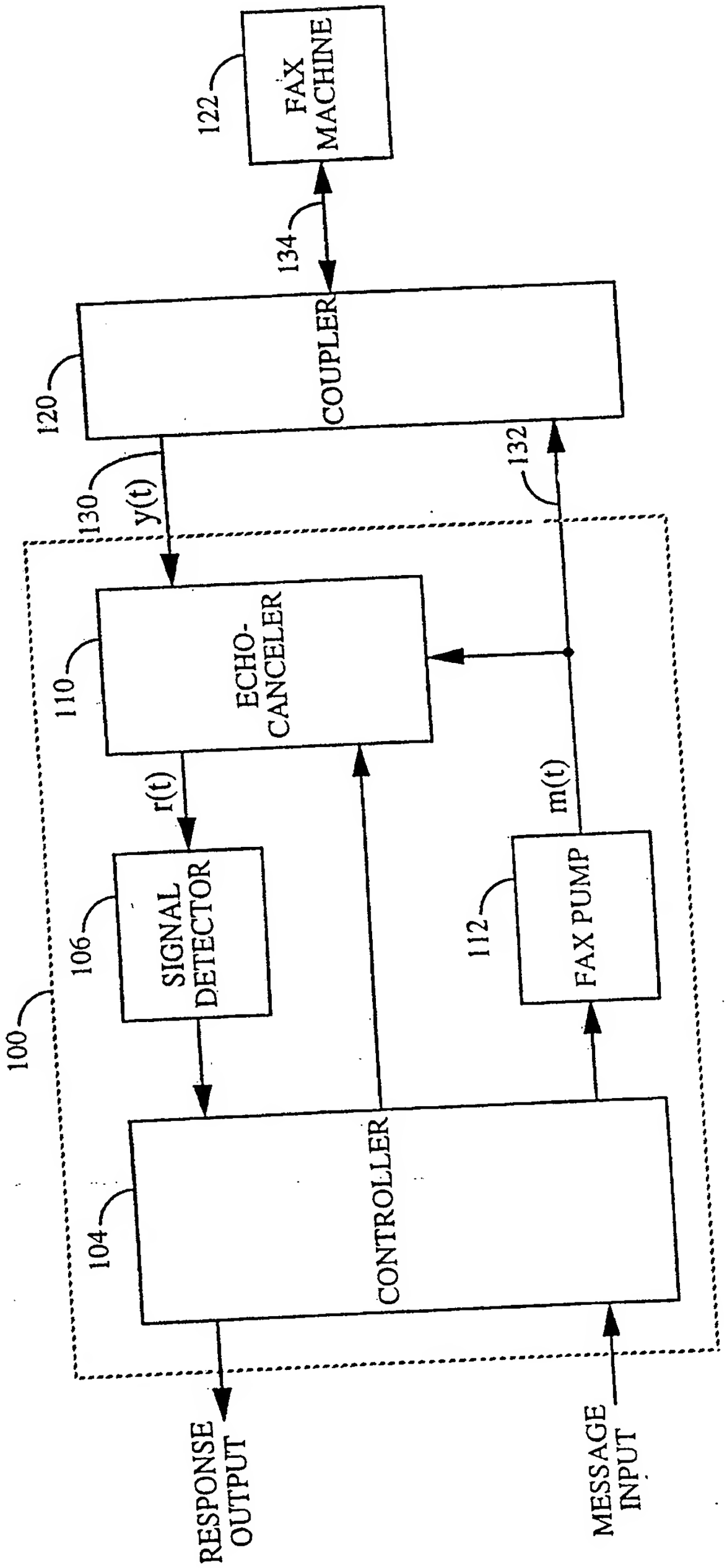


FIG. 3

BNSDOCID: <WO_____9852299A1_I_>

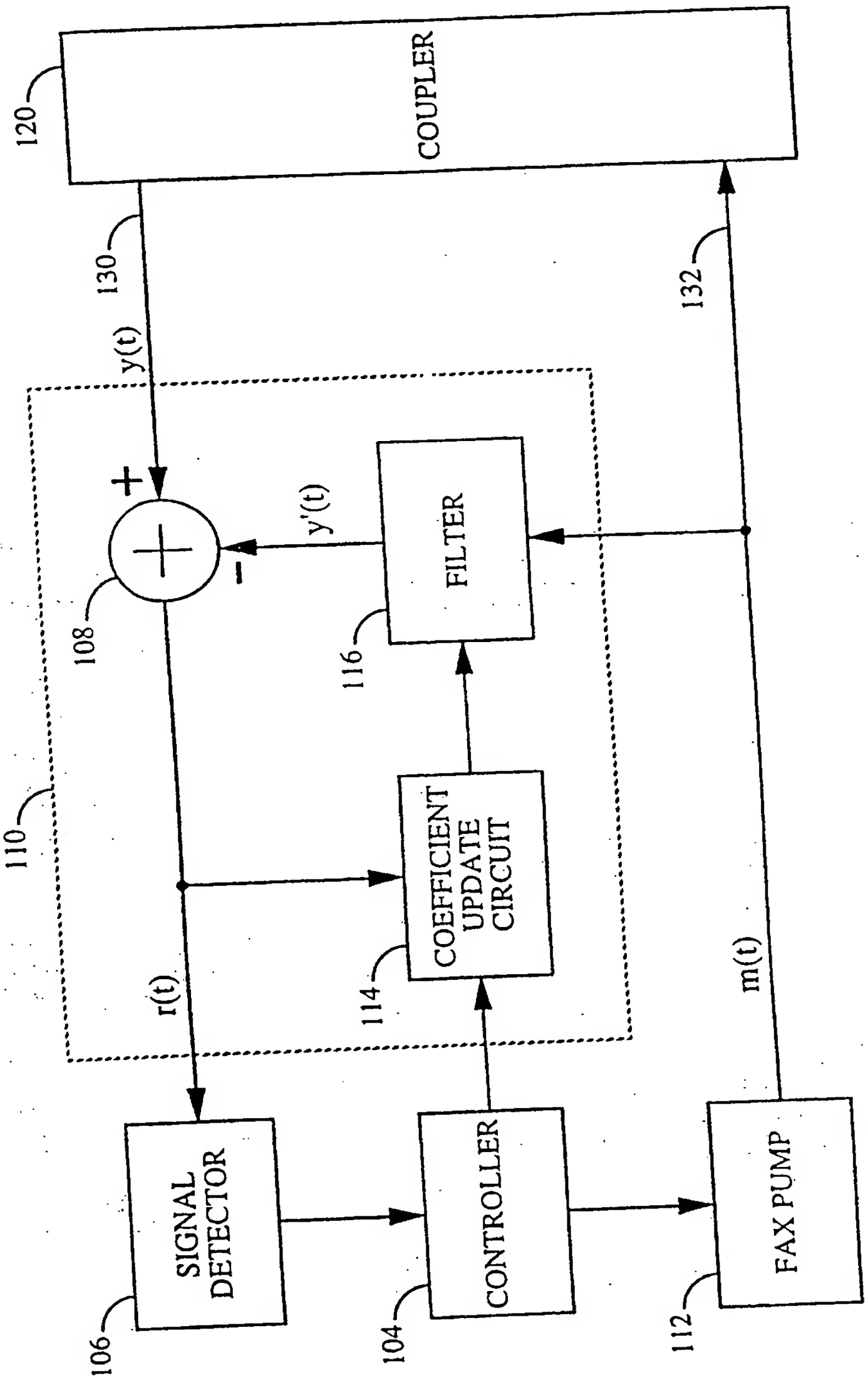


FIG. 4

BNSDOCID: <WO_____9852299A1_I_>

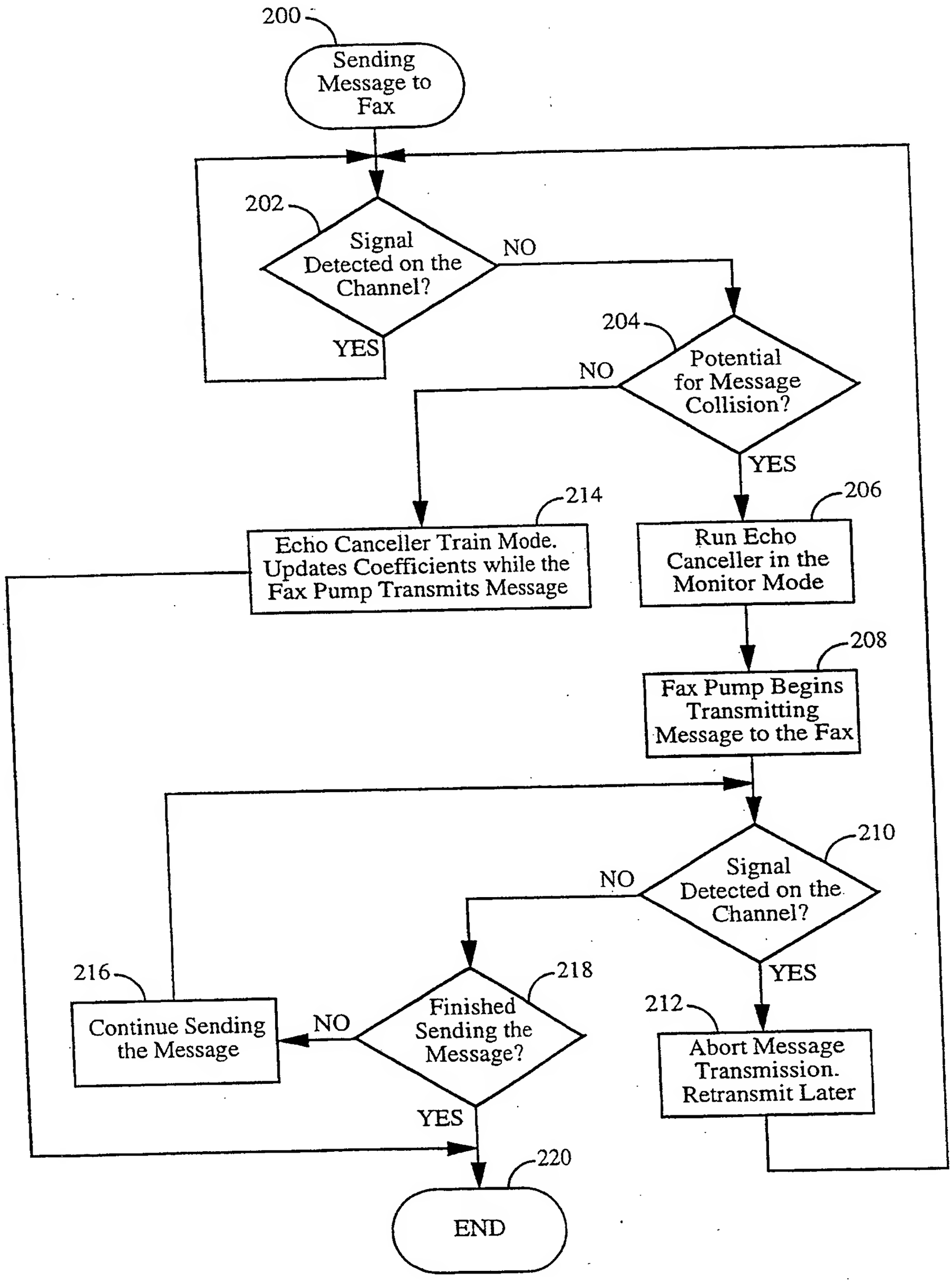
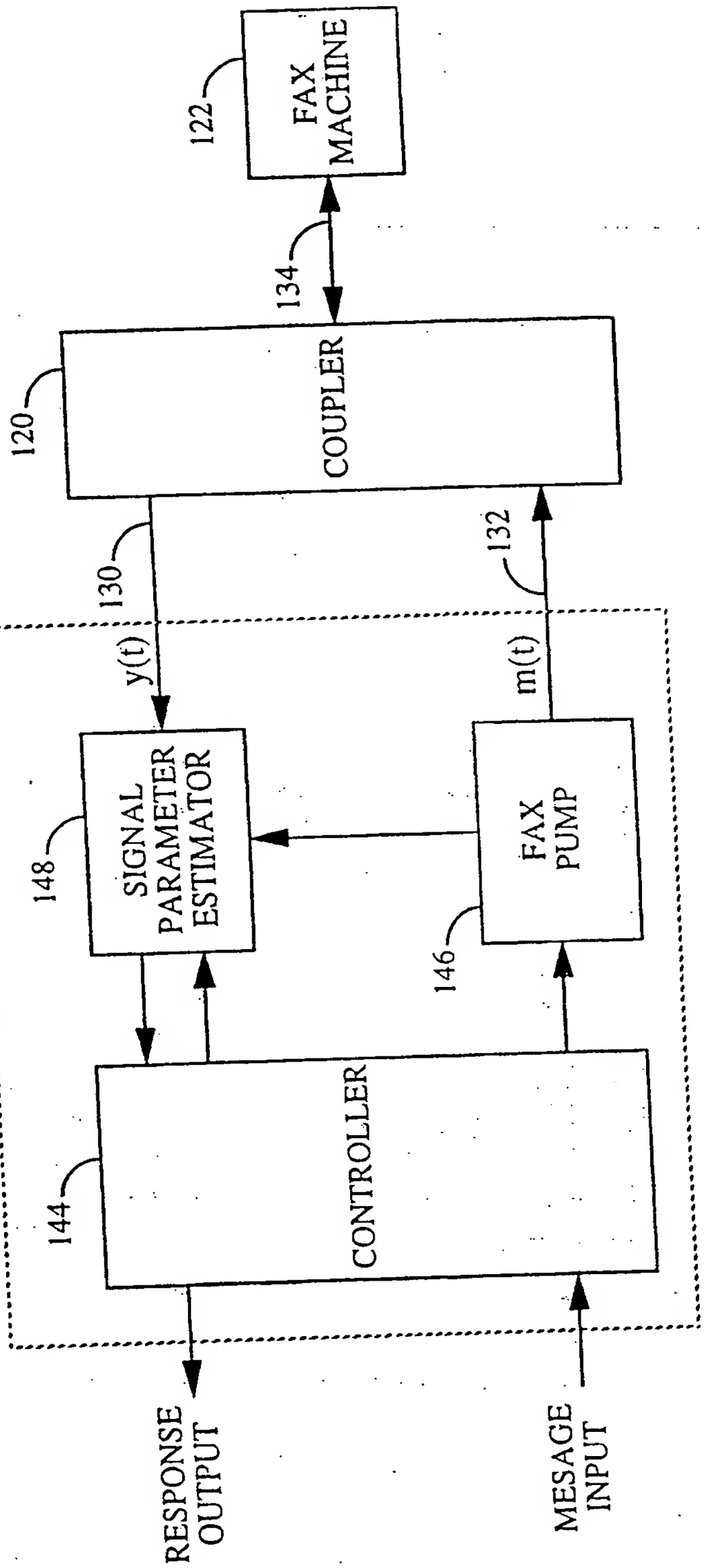


FIG. 5

BNSDOCID: <WO_____9852299A1_I_>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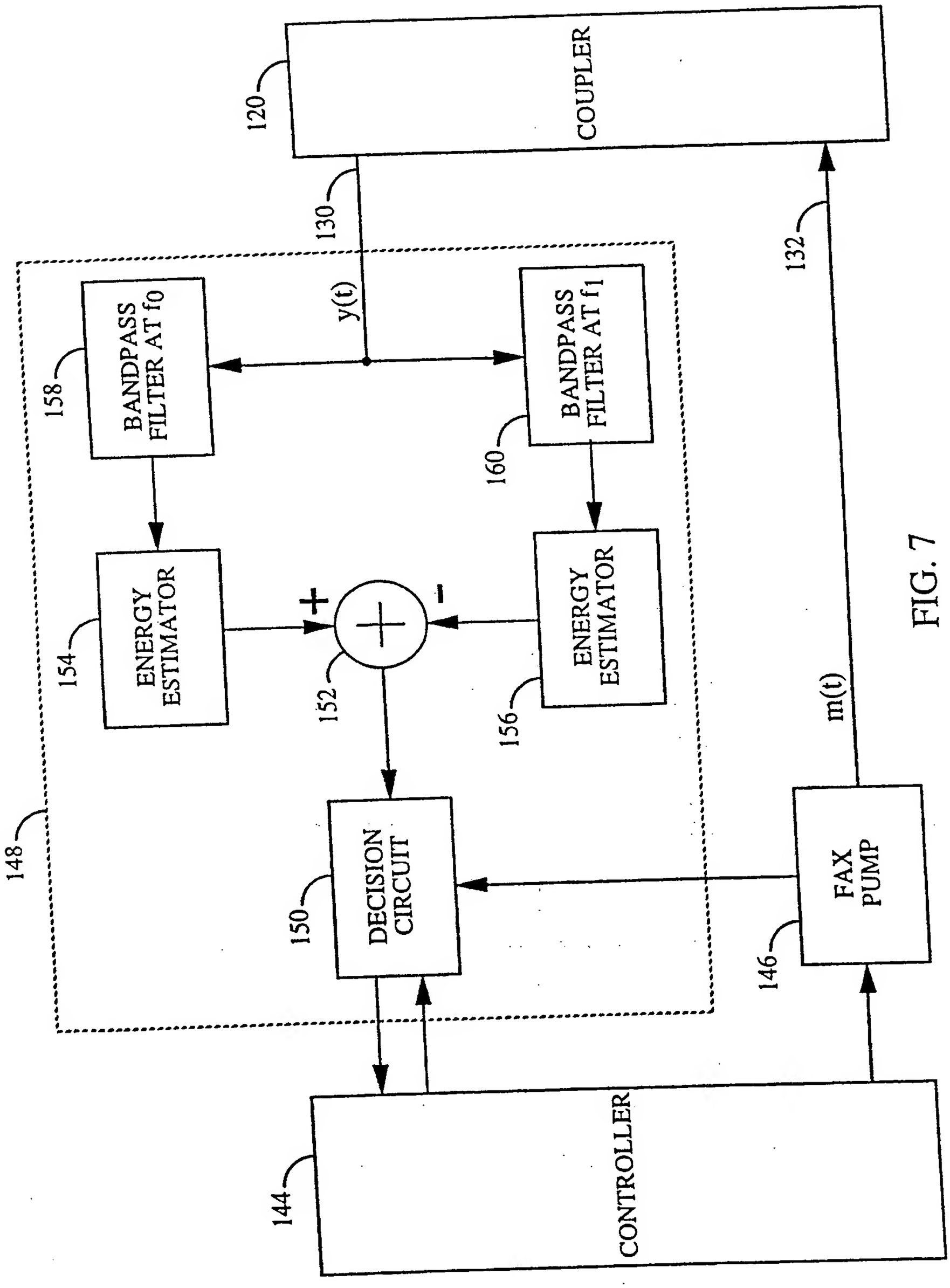
122
134
COUPLER
120
130
y(t)
132
m(t)
SIGNAL PARAMETER ESTIMATOR
148
FAX PUMP
146
102
CONTROLLER
144
RESPONSE OUTPUT
MESAGE INPUT

FIG. 6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COUPLER
130
132
y(t)
158
BANDPASS FILTER AT f_0
BANDPASS FILTER AT f_1
160
154
ENERGY ESTIMATOR
ENERGY ESTIMATOR
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+
-
152
148
150
DECISION CIRCUIT
FAX PUMP
146
m(t)
144
CONTROLLER

FIG. 7

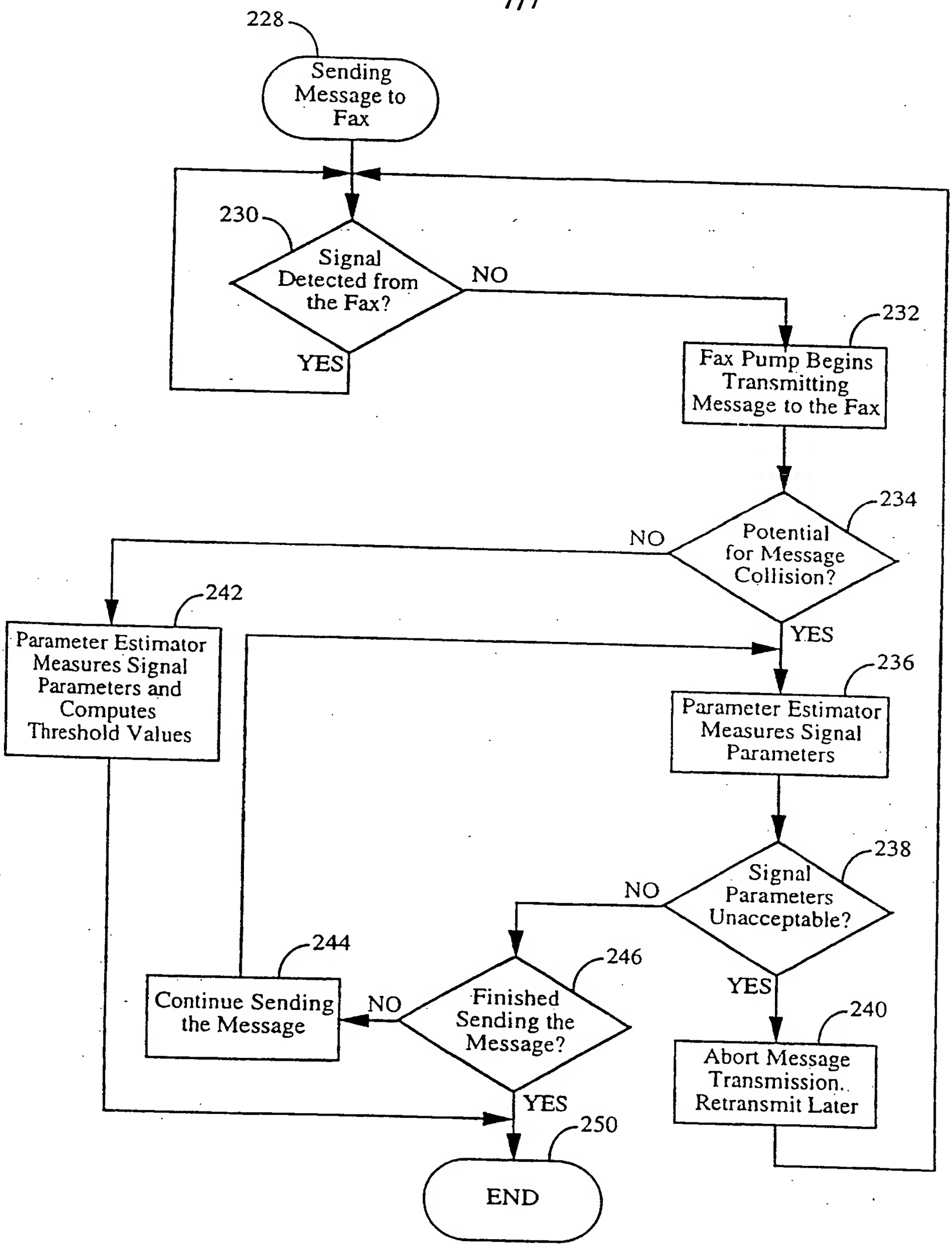

FIG. 8

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INTERNATIONAL SEARCH REPORT

Int ational Application No
PCT/US 98/09927

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/005 H04N1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04N H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 295 136 A (ASHLEY JAMES P ET AL) 15 March 1994 see column 6, line 31 - line 42 see column 7, line 18 - line 46; figures 1,4	1,9,17, 23,28,36
A	US 5 237 429 A (ZUISS THOMAS J ET AL) 17 August 1993 see the whole document	1,9,17, 23,28,36
A	WO 95 23477 A (QUALCOMM INC) 31 August 1995	
A	GB 2 286 739 A (INT MARITIME SATELLITE ORGANIZ ;INT MOBILE SATELLITE ORGANIZAT (GB) 23 August 1995	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
19 August 1998	27/08/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hazel, J

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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